Overview
of
NASA Institute for Advanced Concepts

Dr. Robert A. Cassanova
Director

"Don't let your preoccupation with reality stifle your imagination."
- Robert A. Cassanova

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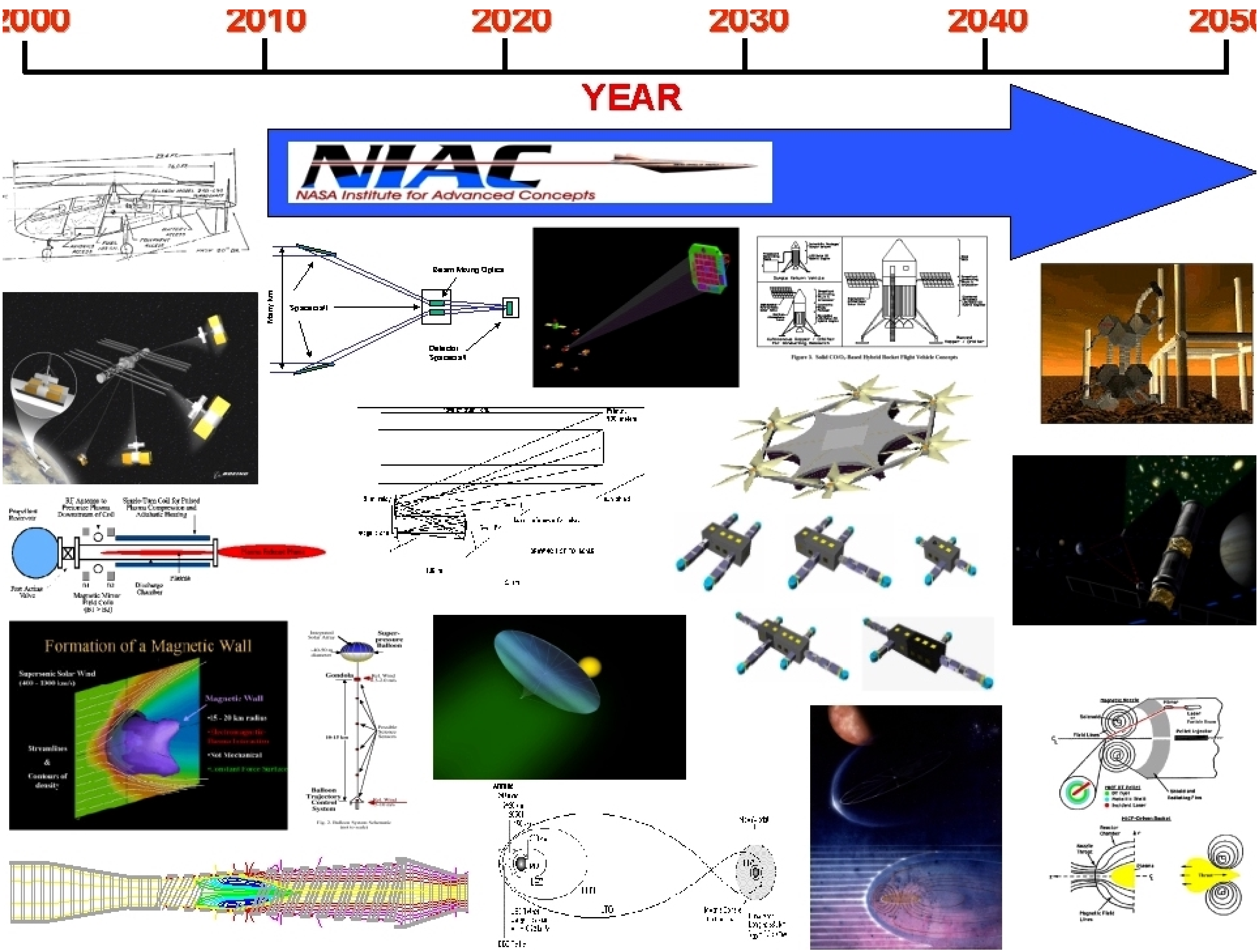

2010
2020
2030
2040
YEAR
NIAC
NASA Institute for Advanced Concepts
Formation of a Magnetic Wall
Supersonic Solar Wind
Magnetic Wall
Streamlines
&
Contours of
density

NIAC
NASA Institute for Advanced Concepts

Now	10 years	20 years	30 years	40 years

NASA PLANS & PROGRAMS

- **NASA Enterprises**
  - *Aerospace Technology*
  - *Space Sciences*
  - *Earth Sciences*
  - *Human Exploration & Development of Space*
- **Operational Missions**
- **Planned Programs & Missions**

NIAC Mission

Revolutionary Advanced Concepts

Architectures

- Overall plan to accomplish a goal.
- A suite of systems, and their operational methods and interrelationships, capable of meeting an overall mission or program objective.

Systems

- The physical embodiment of the architecture
- A suite of equipment, software, and operations methods capable of accomplishing an operational objective.

Technology

Enablers to construct the system: Devices, subsystems, components, design techniques, analysis and modeling generally associated with engineering and scientific disciplines (e.g., aerodynamics, materials, structures, electronics, sensors, chemistry, combustion, plasma dynamics, etc.)

NIAC Mission

Focus on Advanced Concepts

- Must be consistent with NASA's Charter and Strategy.
- Revolutionary, new and not duplicative or an evolution of previously studied concepts.
- An architecture or system described in a mission context.
- Not solely a specific advanced technology or design approach.
- Must potentially have major impact on how future NASA Enterprise missions are accomplished.
- Adequately substantiated with a technical description.
- May be largely independent of existing technology.

"The only way of discovering the limits of the possible is to venture a little way past them into the impossible."
Clarke's Second Law - Sir Arthur C. Clarke

NIAC Science, Exploration & Technology Council Membership

Dr. Burton Edelson - Convener
Dr. David Black
Dr. Jerry Grey
Dr. Aaron Cohen
Mr. Gentry Lee
Dr. Roald Sagdeev
Dr. Taylor Wang
Mr. Peter Bracken
Dr. Lynn Margulis
Dr. Robert Whitehead
Dr. Wes Huntress

NASA's NIAC Coordination Team

ENTERPRISES
John Mankins, M
David Stone, R
Karl Loutinsky, R
Glenn Mucklow, S
Roger Crouch, U
Lou Schuster, Y

NASA COTR
Sharon Garrison, GSFC

CENTERS
Art Murphy, JPL
Gale Allen, KSC
Olga Gonzalez-Sanabria, LeRC
John Cole, MSFC
Kenneth Cox, JSC
Dennis Bushnell, LaRC
Bill St. Cyr, SSC
Steve Whitmore, DFRC
Larry Lasher, ARC
Wayne Hudson, GSFC

NASA OFFICE OF CHIEF TECHNOLOGIST
Murray Hirschbein, AF

Significant Events Since Contract Start

1. Contract began February 10, 1998.
2. Grand Challenges Workshop was held May 20-21, 1998.
3. First Phase I grants began November 1, 1998.
4. NIAC Annual Meeting and USRA/NIAC Technical Symposium was held March 25-26, 1999.
5. Second Phase I grants began June 1, 1999.
6. First Phase II contract awards were announced August 11, 1999.

Definitions: Phase I and II

Phase I Activities

Performance Period: 6 months

Budget: $50K to $75K

Scope: (1) Validate the viability of the proposed concept
(2) Define major feasibility issues

Phase II Activities

Performance Period: 18 - 24 months

Budget: $350K to $500K

Scope: Study major feasibility issues associated with cost, development time, and key technology

"If we are looking for new direction in science, we must look for scientific revolutions. When no scientific revolution is under way, science continues to move ahead along old directions."
Imagined Worlds - *Freeman Dyson,* 1997

Phase I Evaluation Criteria

1. The principle elements (of approximately equal weight) considered in evaluating a proposal are its relevance to NASA's and the NIAC's objectives, intrinsic merit and cost realism. Specific aspects of these elements are as follows:

   a. Is the concept revolutionary rather than evolutionary? To what extent does the proposed activity suggest and explore creative and original concepts?

   b. Is the concept for an architecture or system, and have the benefits been qualified in the context of a future NASA mission?

   c. Is the concept substantiated with a description of applicable scientific and technical disciplines necessary for development?

2. Evaluation of the cost of a proposed effort may include the realism and reasonableness of the proposed cost and available funds.

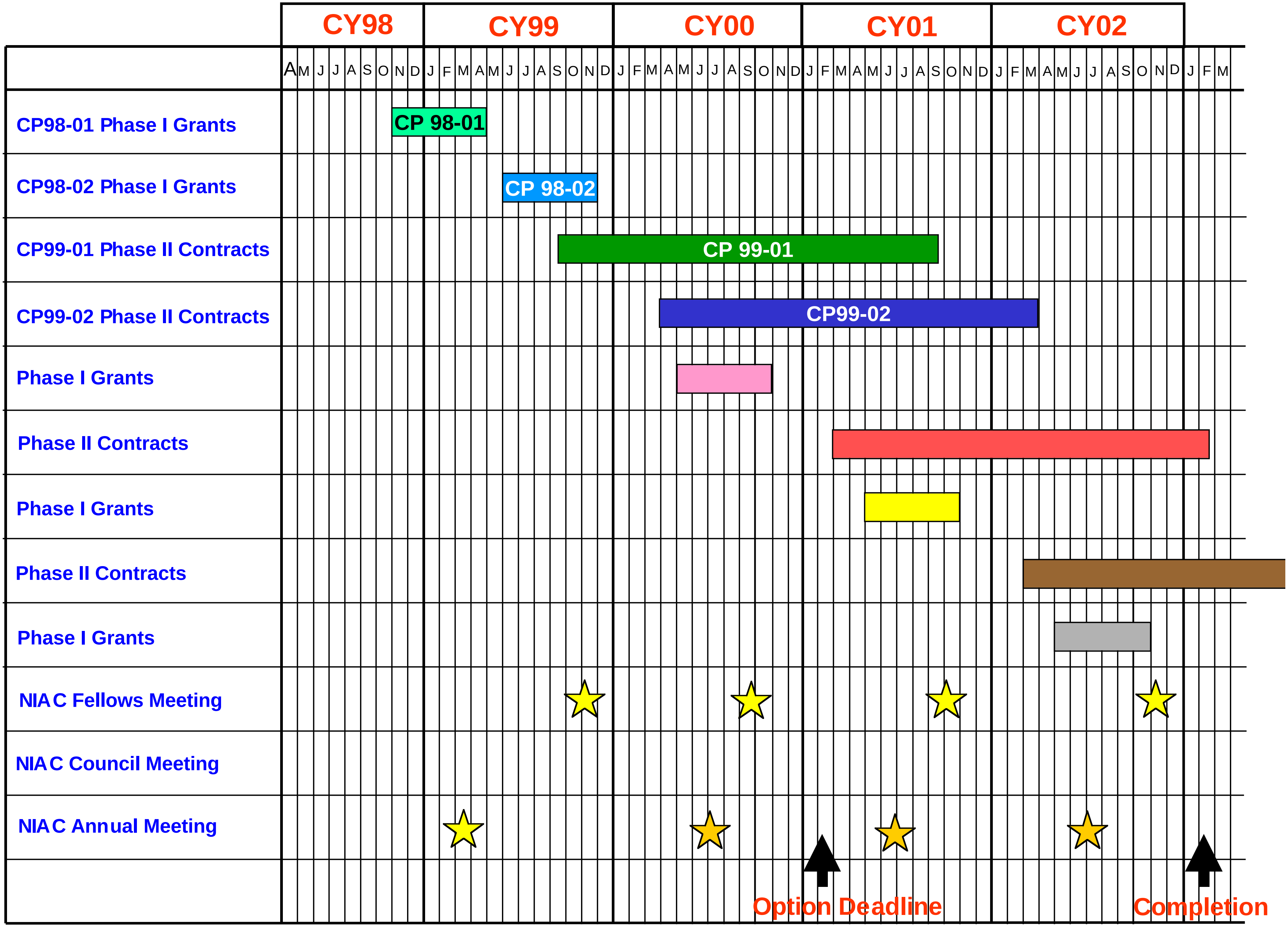
NIAC Phase II Evaluation Criteria

1. Does the proposal continue the development of a revolutionary architecture or system in the context of a future NASA mission? Is the proposed work likely to provide a sound basis for NASA to consider the concept for a future mission or program?

2. Is the concept substantiated with a description of applicable scientific and technical disciplines necessary for development?

3. Has a pathway for development of a technology roadmap been adequately described? Are all of the appropriate enabling technologies identified?

4. Are the programmatic benefits and cost versus performance of the proposed concept adequately described and understood? Does the proposal show the relationship between the concept's complexity and its benefits, cost and performance?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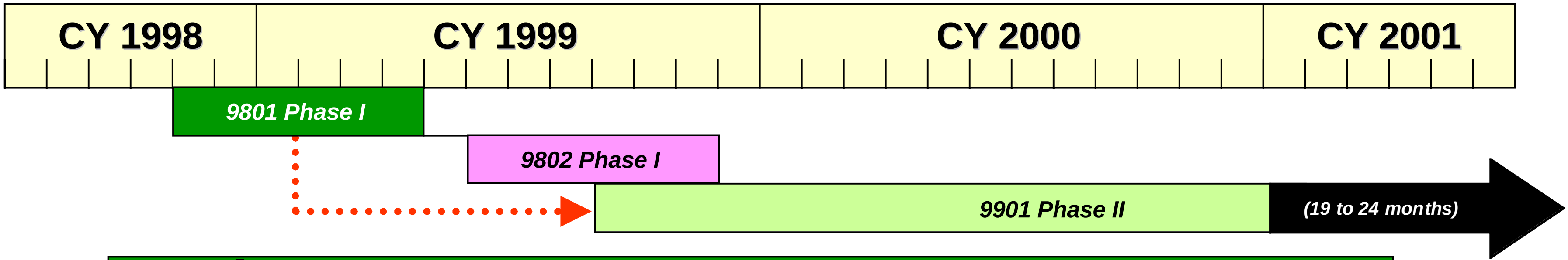
CP98-01 Phase I Grants
CP 98-01
CP98-02 Phase I Grants
CP 98-02
CP99-01 Phase II Contracts
CP 99-01
CP99-02 Phase II Contracts
CP99-02
Phase I Grants
Phase II Contracts
Phase I Grants
Phase II Contracts
Phase I Grants
NIAC Fellows Meeting
NIAC Council Meeting
NIAC Annual Meeting
Option Deadline
Completion



CP9801 AWARDEES *Phase I*	1)	Ivan Bekey	*A Structureless Extremely Large Yet Very Lightweight Swarm Array Space Telescope*
	2)	Mark E. Campbell	*Intelligent Satellite Teams (ISTs) for Space*
	3)	Steven Dubowsky	*Self-Transforming Planetary Explorers*
	4)	Robert E. Gold	*SHIELD: A Comprehensive Earth Protection System*
	5)	Paul Gorenstein	*An Ultra-High Throughput X-Ray Observatory With A New Mission Architecture*
	6)	Clark W. Hawk	*Pulsed Plasma Power Generation*
	7)	Steven D. Howe	*Enabling Exploration of Deep Space: High Density Storage of Antimatter*
	8)	Robert P. Hoyt	*Cislunar Tether Transport System*
	9)	Ron Jacobs	*A Biologically-Inspired MARS Walker*
	10)	Ilan Kroo	*Mesicopter: A Meso-Scale Flight Vehicle for Atmospheric Sensing*
	11)	Geoffrey A. Landis	*Advanced Solar- and Laser-Pushed Lightsail Concepts*
	12)	Ralph L. McNutt, Jr.	*A Realistic Interstellar Explorer*
	13)	Clint Seward	*Low-Cost Space Transportation Using Electron Spiral Toroid (EST) Propulsion*
	14)	Charles M. Stancil	*Electric Toroid Rotor Technology Development*
	15)	Robert M. Winglee	*Mini-Magnetospheric Plasma Propulsion*
	16)	Neville J. Woolf	*Very Large Optics for the Study of Extrasolar Terrestrial Planets*
CP9802 AWARDEES *Phase I*	1)	Thomas J. Bogar	*Hypersonic Airplane Space Tether Orbital Launch System*
	2)	Webster Cash	*X-Ray Interferometry: Ultimate Astronomical Imaging*
	3)	Cindy Christensen	*Ultralight Solar Sails for Interstellar Travel*
	4)	Shane Farritor	*A Modular Robotic System to Support the Surface Operations of Human Mars Exploration*
	5)	Paul D. Hoskins	*An Advanced Counter-Rotating Disk Wing Aircraft Concept*
	6)	Timothy Howard	*Planetary-Scale Astronomical Bench*
	7)	Terry Kammash	*Antiproton-Driven, Magnetically-Insulated Inertial Fusion (MICF) Propulsion System*
	8)	Laurence E. LaForge	*Architectures and Algorithms for Self-Healing Autonomous Spacecraft*
	9)	Michael LaPointe	*Primary Propulsion for Piloted Deep Space Exploration*
	10)	Kerry T. Nock	*Global Constellation of Stratospheric Scientific Platforms*
	11)	Eric E. Rice	*Development of Lunar Ice Recovery System Architecture*
	12)	Eric E. Rice	*Advanced System Concept for Total ISRU Based Propulsion & Power Systems for Unmanned and Manned Mars Exploration*
	13)	John Slough	*Rapid Manned Mars Mission With A Propagating Magnetic Wave Plasma*
	14)	Robert Zubrin	*The Magnetic Sail*
CP9901 AWARDEES *Phase II*	1)	Robert M. Winglee	*Mini-Magnetospheric Plasma Propulsion*
	2)	Ilan Kroo	*Meso-Scale Flight Vehicle for Atmospheric Sensing*
	3)	Steven Dubowsky	*Self-Transforming Robotic Planetary Explorers*
	4)	Robert P. Hoyt	*Moon and Mars Orbiting Spinning Tether Transport (MMOSTT) Architecture*
	5)	Neville J. Woolf	*Very Large Optics for the Study of Extrasolar Planets*
	6)	Paul Gorenstein	*An Ultra High Throughput X-Ray Astronomy Observatory With A New Mission Architecture*

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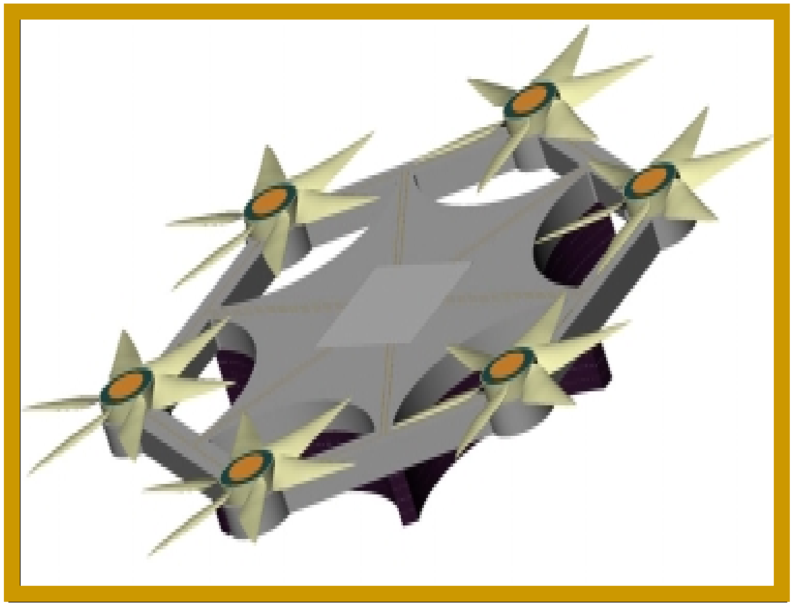
CP9801 Awards

Phase II	PI Name & Organization	Advanced Concept Proposal Title	NASA Enterprise			
			AST	HEDS	SS	ES
	Bekey, Ivan *Bekey Designs, Inc.*	A Structureless Extremely Large Yet Very Lightweight Swarm Array Space Telescope			Primary	
	Campbell, Mark E. *University of Washington*	Intelligent Satellite Teams (ISTs) for Space			Primary	Secondary
★	Dubowsky, Steven *MIT*	Self-Transforming Planetary Explorers		Primary	Secondary	
	Gold, Robert E. *Johns Hopkins University*	SHIELD: A Comprehensive Earth Protection System			Primary	
★	Gorenstein, Paul *Smithsonian Institute*	An Ultra-High Throughput X-Ray Observatory With A New Mission Architecture			Primary	
	Hawk, Clark W. *University of Alabama-Huntsville*	Pulsed Plasma Power Generation	Primary	Secondary		
	Howe, Steven D. *Synergistics Technologies, Inc.*	Enabling Exploration of Deep Space: High Density Storage of Antimatter	Primary	Secondary		
★	Hoyt, Robert P. *Tethers Unlimited*	Cislunar Tether Transport System	Primary	Secondary	Secondary	
	Jacobs, Ron *Intelligent Inference Systems Corp.*	A Biologically-Inspired MARS Walker		Primary	Secondary	
★	Kroo, Ilan *Stanford University*	Mesicopter: A Meso-Scale Flight Vehicle for Atmospheric Sensing	Primary		Secondary	Secondary
	Landis, Geoffrey A. *Ohio Aerospace Institute*	Advanced Solar- and Laser-Pushed Lightsail Concepts	Primary		Primary	
	McNutt, Jr., Ralph L. *Johns Hopkins University*	A Realistic Interstellar Explorer			Primary	
	Seward, Clint *Electron Power Systems, Inc.*	Low Cost Space Transportation Using Electron Spiral Toroid (EST) Propulsion	Primary	Secondary		
	Stancil, Charles M. *Georgia Tech Research Institute*	Electric Toroid Rotor Technology Development	Primary			Primary
★	Winglee, Robert M. *University of Washington*	Mini-Magnetospheric Plasma Propulsion	Primary		Primary	
★	Woolf, Neville J. *University of Arizona*	Very Large Optics for the Study of Extrasolar Terrestrial Planets			Primary	Secondary

Primary
Secondary

Ilan Kroo
Stanford University

"Meso-Scale Flight Vehicle for Atmospheric Sensing"



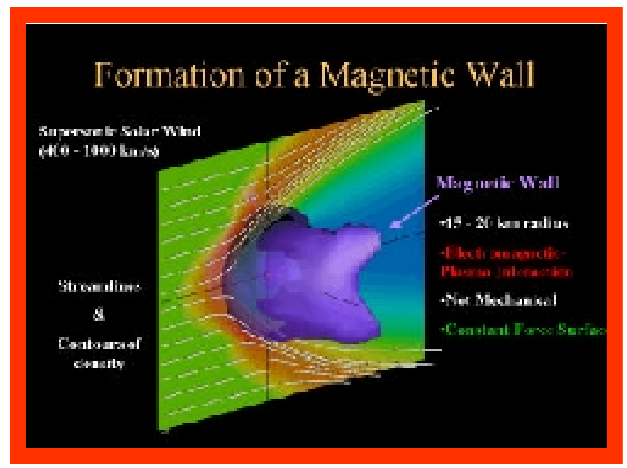
A team of researchers from Stanford University, with support from industrial partners, Intel and SRI, propose to design and build the 'mesicopter', a centimeter-size electric helicopter designed to stay airborne while carrying its own power supply. This device represents a revolutionary class of flight vehicles at an unprecedented size and suggests a range of potential uses. Mesicopters may be used on earth for atmospheric science, permitting in-situ measurements of meteorological phenomena such as downbursts and wind shear, and on planets like Mars where atmospheric flight permits unique opportunities for exploration. Swarms of mesicopters could provide atmospheric scientists with information not obtainable using current techniques and could aid in the understanding of phenomena on Mars and other simple sensing tasks may be feasible with these very low cost aerial micro-robots. The mesicopter will pioneer the application of new aerodynamic design concepts and novel fabrication techniques. These advanced may ultimately allow the mesicopter to be scaled down to millimeter dimensions, although nearer term applications exist for 1 - 10 cm mesicopters. Significant challenges are anticipated in the areas of materials, battery technology, aerodynamics, control and testing. In the first phase of the program, basic aerodynamic design methods were developed and fabrication processes evaluated. Successful constrained tests of a 4-rotor mesicopter demonstrated the basic feasibility of the design and manufacturing concepts.

Robert M. Winglee

University of Washington

"The Mini-Magnetospheric Plasma Propulsion System, M^2P^2"

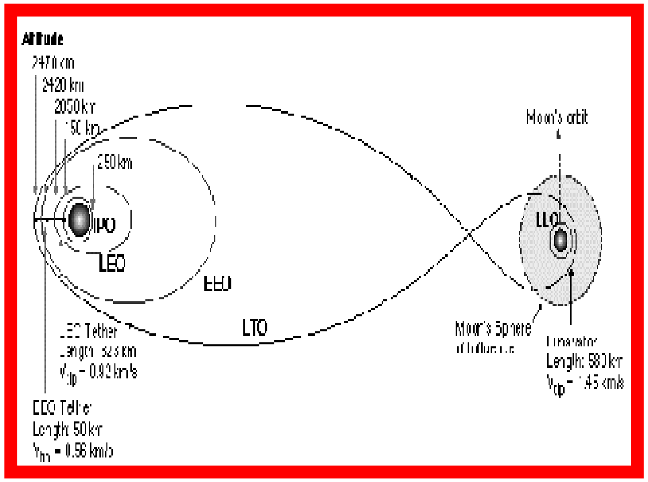
Mini-Magnetospheric Plasma Propulsion ($M^2 P^2$) is a revolutionary plasma propulsion concept that will enable spacecraft to attain unprecedented speeds for minimal energy and mass requirements. The high efficiency and specific impulse attained by the system is due to its utilization of ambient energy, in this case the energy of the solar wind, to provide the enhanced thrust. Coupling to the solar wind is produced through a large-scale magnetic bubble or mini-magnetosphere generated by the injection of plasma into the magnetic field supported by solenoid coils on the spacecraft. This inflation is driven by electromagnetic processes so that the material and deployment problems associated with mechanical sails are eliminated. The concept has been rigorously tested through computer simulations, and key components for a laboratory prototype have been designed and assembled. Because all the enabling technology is presently available, the proposed work could have almost immediate and monumental impact on NASA's long range strategic plans for missions out of the solar system and between the planets. Specifications and proposed plans for assembling and testing of a prototype suitable for an Interstellar Precursor Mission are given. For a nominal configuration utilizing only solar electric cells for power, the $M^2 P^2$ will produce a magnetic barrier approximately 15 - 20 km in radius, which would accelerate a 70 - 140 kg payload to speeds of about 50 - 80 km/s. This system would require only a few kilowatts of power to support the solenoid field coils and the plasma injection and only a few tens of kilograms of propellant is needed. Successful implementation of the system would revolutionize exploration of the solar system with its unprecedented mobility while utilizing only solar electric cells. If larger electric systems become available that could provide tens of kilowatts of power or if the power is augmented by a 100 W radioisotope system, then speeds in excess of 100 km/s can be attained.



Robert P. Hoyt
Tethers Unlimited, Inc.

"Moon and Mars Orbiting Spinning Tether Transport (MMOSTT) Architecture"

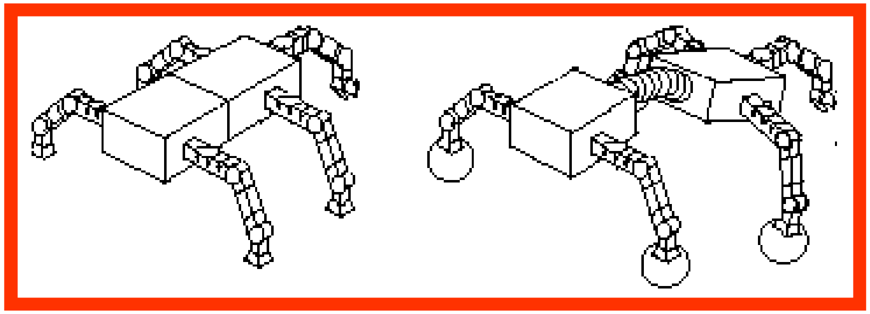
Systems of rotating momentum-exchange tether facilities can repeatedly transport payloads between low Earth orbit, geostationary orbit, the Moon, and Mars with minimal propellant expenditure. The Phase I effort developed a design for a Cislunar Tether Transport System that uses one tether in elliptical, equatorial Earth orbit and one tether in low lunar orbit. Numerical modeling verified that this system could provide round-trip travel between LEO and the surface of the Moon with near-zero propellant requirements. Using currently available tether materials, such a system would require a total mass of less than 28 times the mass of the payloads it can handle. Because a rocket-based system would require a propellant mass of at least 15 times the payload mass to perform the same job, the fully reusable tether system would be competitive from a mass perspective after only two trips, and would provide large cost savings for frequent round-trip travel. The Phase I effort also developed a conceptual design for a tether system for rapid Earth-Mars travel. In the Phase II effort, we will combine and improve these system designs to develop a tether transportation architecture that can provide low-cost transport to the Moon, Mars, and elsewhere I the solar system. In order to determine specific requirements for the hardware and technologies needed for tether transport systems, we will develop a detailed system level design for an Earth-Orbit Tether Boost Facility. We will also investigate concepts for enabling payload capsules to rendezvous with rotating tether facilities, and develop methods to minimize propellant requirements and maximize rendezvous windows. We will then develop a detailed design for a low-cost flight experiment to begin demonstrating the momentum-exchange tether technologies needed to create tether transport systems.



Steven Dubowsky

Massachusetts Institute of Technology

"Self-Transforming Robotic Planetary Explorers"



The exploration and development of the planets and moons of the solar system in the next 10 to 40 years are stated goals of NASA and the international space science community. These missions will require robot scouts to lead the way, exploring, mapping, and constructing facilities. The fixed configuration planetary robots of today will not be able to meet the demands of these missions forecast for the coming millenium. The proposed research program would study the concept of self-transforming robotic planetary explorers to meet the needs of future missions. A self-transforming system would be able to change its configuration to overcome a wide range of physical obstacles and perform a wide range of tasks. In order to achieve self-transforming robots for planetary exploration, conventional complex and heavy physical components, such as gears, motors and bearings, must be replaced by a new family of elements. Here, lightweight, compliant elements with embedded actuation are proposed. The actuation would be binary in nature, simplifying the control architecture. The physical system would allow the robot to make both geometric and topological configuration changes. It is proposed that the configuration planning would be handled with genetic algorithms. This proposed research would develop the concepts and technologies that will be relevant to the needs of NASA in the 10-40 year period. This program will focus on studying the underlying, fundamental physics and feasibility of self-transforming robotic planetary explorers.

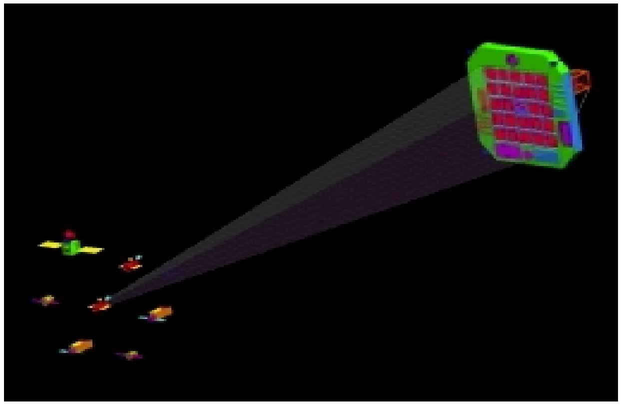
NASA Institute for Advanced Concepts

Paul Gorenstein

Smithsonian Institute, Astrophysical Observatory

"An Ultra-High Throughput X-Ray Astronomy Observatory with A New Mission Architecture"

We propose a Phase II study of an ultra high throughput X-ray observatory with new architectures for the mission and the telescope. It is situated at the quasi-stable L2 point and contains a grazing incidence telescope composed of controllable segments. The telescope diameter is 30m, focal length is up to 300m, and it has arsecond resolution. The effective area goal is 2 million square cm which is a factor of 10 to 100 larger than the "Next Generation" X-ray observatories of NASA and ESA. The telescope and several detectors are aboard separate spacecrafts with no physical connections. Each spacecraft has an attitude control and propulsion system employing an ion drive engine. A detector actively in use stations itself at the focus within several millimeters with fine thrusts as needed from the ion engines. It moves 50-300m to a new position as the telescope changes viewing direction. The advantages of



this architecture are a substantial reduction in the mass, volume, and launch costs plus the ability to replace detectors by launching a small spacecraft. The great challenge is constructing the very large telescope and deploying it at L2. The only option appears to be in situ assembly of telescope segments delivered incrementally over several years. During Phase II we will also study a potentially less expensive method for going to L2 from LEO by climbing slowly with fine thrusts from ion engines operating on solar power.

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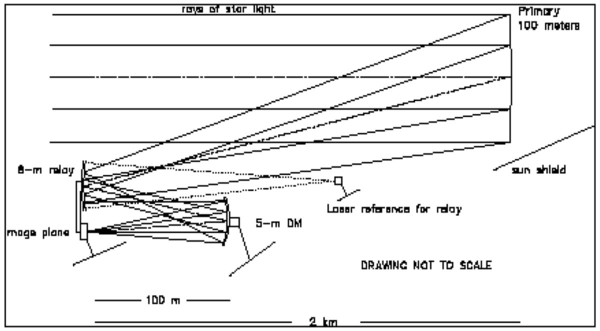
Neville J. Woolf
Steward Observatory, University of Arizona

“Very Large Optics for the Study of Extrasolar Terrestrial Planets”

NASA’s Terrestrial Planet Finder (TPF), scheduled for launch in 2010 is aimed at detecting Earth-like planets of other stars. If, as we hope, temperate planets with strong water absorption indicating oceans are found, and possibly chemical signs of life, then we will want larger telescopes capable of detailed atmospheric spectroscopy and ultimately surface imaging. Under the Phase I grant, we have studied concepts of space telescopes with collection areas ranging from around 500 m 2 for the next level of spectroscopy to ~ 1,000,000 m 2 to map surface features. Even using new NGST and TPF mirror technology now under development, such systems would weigh many tons. We, therefore, explored new ways to exploit the space environment. Free from gravity and wind, individual optical elements of gossamer construction can be orbited around the sun in formation to form multi-kilometer scale systems quite impossible on Earth. We developed a concept to greatly extend the light grasp and resolution of a telescope by directing additional starlight into it with the aid of optical flats. We demonstrated explicitly a concept for making flats made as stretched metalized plastic (or metal) membranes, of extremely light weight. Launch and manufacturing costs should be low. We propose in Phase II to analyze novel optical designs for imaging and interferometric systems built in this way, to study issues of thermal and cryogenic control, and orbital and station=keeping constraints. We will study the limits of light-weighting and surface quality for both flat and powered collector mirror elements with active figure control, both at a fundamental materials level and through lab models. Taking advantage of Arizona’s unique optical facilities where powered mirrors of 20 and 12 kg/m 2 areal density are already being evaluated, we plan to demonstrate optical diffraction performance at densities up to 100 times lighter.



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NASA Institute for Advanced Concepts

CP9802 Awards

PI Name & Organization	Advanced Concept Proposal Title	NASA Enterprise			
		AST	HEDS	SS	ES
Bogar, Thomas J. *McDonnell Douglas Corp.*	Hypersonic Airplane Space Tether Orbital Launch System				
Cash, Webster *University of Colorado*	X-Ray Interferometry: Ultimate Astronomical Imaging				
Christensen, Cindy *Pioneer Astronautics*	Ultralight Solar Sails for Interstellar Travel				
Farritor, Shane *University of Nebraska-Lincoln*	A Modular Robotic System to Support the Surface Operations of Human Mars Exploration				
Hoskins, Paul D. *Diversitech Inc.*	An Advanced Counter-Rotating Disk Wing Aircraft Concept				
Howard, Timothy *SVS Systems Inc.*	Planetary-Scale Astronomical Bench				
Kammash, Terry *University of Michigan*	Antiproton-Driven, Magnetically Insulated Inertial Fusion (MICF) Propulsion System				
LaForge, Laurence E. *The Right Stuff of Tahoe, Inc.*	Architectures & Algorithms for Self-Healing Autonomous Spacecraft				
LaPointe, Michael *Horizon Tech. Development Group*	Primary Propulsion for Piloted Deep Space Exploration				
Nock, Kerry T. *Global Aerospace Corporation*	Global Constellation of Stratospheric Scientific Platforms				
Rice, Eric E. *Orbital Technologies Corporation*	Development of Lunar Ice Recovery System Architecture				
Rice, Eric E. *Orbital Technologies Corporation*	Advanced System Concept for Total ISRU Based Propulsion and Power Systems for Unmanned and Manned Mars Exploration				
Slough, John *MSNW*	Rapid Manned Mars Mission With A Propagating Magnetic Wave Plasma Accelerator				
Zubrin, Robert *Pioneer Astronautics*	The Magnetic Sail				

Primary
Secondary

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Next Phase I Call for Proposals

- Phase I Call for Proposals (CP 99-03) released September 17, 1999
- Due date: January 31, 2000
- Viewed and downloaded from NIAC website, http://www.niac.usra.edu
- Technical proposal: 12 page limit
- Cost proposal: limited to a maximum of $75K for a 6 month study
- Technical and cost proposals must be submitted as a .PDF file attachment to an email
- Technical Scope:
  - ---Revolutionary advanced concepts for all NASA Enterprises Areas
  - ---Special interest in Earth Sciences, Aeronautics, Biology and Software

→ Read instructions in CP 99-03 ←